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Trichoderma as a Bio-Control Agent - A Review

Manpreet Kour* and Lovepreet Kaur

Department of Pathology, University Institute of Agriculture, Chandigarh University, Garuan Mohali - 140413, India

**Corresponding author*

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ABSTRACT

Trichoderma spp. is free living filamentous fungi. They are cosmopolitan and versatile in nature. They have the potential to produce several enzymes that can degrade the cell wall materials. Also, they release a number of fungi toxic substances that can inhibit the growth of the fungal pathogens. Many mechanisms have been described on how *Trichoderma* exert beneficial effects on plants as a bio-control agent. But due to its versatile nature, its potential cannot be explored to its full extent. The fungus is also a decomposer of cellulosic waste materials. Recent discoveries show that the fungi not only act as biocontrol agents, but also stimulate plant resistance, and plant growth and development resulting in an increase in crop production. The biocontrol activity involving mycoparasitism, antibiotics and competition for nutrients, also induces defence responses or systemic resistance responses in plants. These responses are an important part of *Trichoderma* in biocontrol program. *Trichoderma* spp. has been widely used in agricultural applications due to its well known biological control mechanism. The usage of this microbial inoculant in *Trichoderma*-based products attracts the attention of researchers to discover more on other potential benefits of *Trichoderma* spp.

Introduction

In the current global scenario, with a constant increase in the world population and the damages produced by climate change, ensuring high and quality yields requires the use of sustainable and efficient strategies. *Trichoderma* spp. significantly suppresses the growth of plant pathogenic microorganisms and regulates the rate of plant growth. Recent works have shown that common plant disease such as root rot disease, damping off, wilt, fruit rot and other plant diseases can be controlled by *Trichoderma* spp. The hostile activity of *Trichoderma* species showed that it is parasitic on many soil-borne and foliar plant pathogens. Recent studies showed that this fungus not only acts as biocontrol agent but also stimulates plant resistance, plant growth and development resulting in an increase in crop production. Besides, the interaction between plant and *Trichoderma* spp. successfully regulate root architecture, increase the length of lateral and primary root that result in the effectiveness of nutrient uptake by the plant (Cai *et al.,* 2013; Naseby *et al.,* 2000; Yedidia *et al.,* 2001).

Since the challenges in coping with issues in the agriculture industry have grown tremendously, sustainable strategies by using biological control approach are necessary. Thus, the use of *Trichoderma* sp. as a biological agent seems to be an excellent approach. This review presents a compilation of studies and findings that discover the potentiality of *Trichoderma* sp. as a plant growth promoter agent, a biocontrol agent of plant disease, biological agent for bioremediation and natural decomposition agent. Due to the agricultural losses caused by insect pests and the serious environmental damage derived from the massive use of chemical insecticides, the need to search for new alternatives in pest control is clear.

Trichoderma Genus

Trichoderma term has been derived from two words thrix (hair) and derma (skin). It is free living filamentous fungi that reproduce asexually. It is a good biocontrol agent as it is widely spread, strong opportunistic invaders, avirulant plant symbionts, competes for food and act as mycoparasite. On the basis of these properties this fungi is ecologically sound and ubiquitous (Elad, 2000).

Facts to know about *Trichoderma*

Trichoderma naturally present in most soils. Commercialization of *Trichoderma* biofertilizer raises hope in farmers. *Trichoderma* used in almost all type of crops, with or without any amendments, but if *Trichoderma* biofertilizer is used as an amendment with compost may gives better results than any other fertilizer. It minimizes the use of traditional fertilizer based on NPK. It improves the uptake of micronutrients to plants such as Cu, Zn, Fe, Na etc. and helps in solubilization of phosphate in soil and available to plants. *Trichoderma* improves overall plant health, by creating a positive environment with symbiotic relationship with plants and releases various types of secondary metabolites including, growth hormones, endochitinase, proteolytic enzymes (Benitez *et al.,* 2004) and benefits the plants by taking advantage of plant-microbe interactions. The biofertilizer also used as soil conditioner, improves the population of plant beneficial microorganisms in soil. It helps in mitigating green house gases like Carbon dioxide and methane, a great cause for global warming (CSIR-India) (Abu *et al.,* 2011).

Growth Promoting Activities

Root growth in bitter gourd, loofha and cucumber was detected by using several strains of *Trichoderma* sp., isolated from rhizosphere. Significant increase in seedling height, leaf area, root exploration and root dry weight was recorded to produce by the application of *Trichoderma* strains under greenhouse conditions (Lo and Lin, 2002).

Addition to this, increase in chlorophyll concentration was also observed due to *Trichoderma* application increased seedling germination and control of seed borne *M. phaseolina* was observed when Mung bean seeds were treated with conidial suspension of three *Trichoderma* sp. viz., *T. hanianum, T. hamatum* and *T. Viride* (Rahman *et al.,* 2009)

Fungi as insect pests' biocontrol agents

There are plants that behave as entomopathogens and can be used as effective biocontrol agents, known as biopesticides, against different agricultural pest insects (Sindhu *et al.,* 2017). Bacteria can act through the production of toxins, for example Bacillus thuringiensis, insecticidal secondary metabolites, such as Photorhabdus luminescens, or direct parasitism, as Bacillus cereus or Pseudomonas entomophila (Sindhu *et al.,* 2017).

Different viruses (Sindhu *et al.,* 2017; Singh *et al.,* 2019), cyanobacteria (Poveda, 2020a), protozoa (Sindhu *et al.,* 2017), nematodes (Sindhu *et al.,* 2017; Singh *et al.,* 2019) and fungi (Sindhu *et al.,* 2017; Singh *et al.,* 2019) with great entomopathogenic capacity have also been reported as bio-pesticides in agriculture.

Trichoderma and Its Interaction with Microorganism

Trichoderma is used for different purposes in agriculture crop production. *Trichoderma* interacts with other microorganisms, but mainly with pathogenic fungi (Druzhinina *et al.,* 2006) (Harman GE 2006).

These interactions include hyperparasitism, competition, and antibiosis (Błaszczyk *et al.,* 2014). The competition for food, nutrients, and space by modifying environmental conditions suppressed the activity of other fungi (Benítez *et al.,* 2004). Various literatures regarding *Trichoderma sp*. to combat with plant pathogenic microorganisms like *Rhizoctonia solani*, *Pythium ultimum* and *Botrytis cinerea*.

Application

Seed treatment – 8 to 10 gm per 50 ml water for 1 kg seeds b) Seedling – 250- 500 gm per 50 Liter of water c) Soil Drenching – 1-2 kg per Acre (200 Liter of water)

Formulation

Trichoderma formulations are available in many brand names, with minimum 2 x 109 or 3 x 106 cfu per gram in carrier material.

Recommendation

The *Trichoderma* biofertilizer can be used in many crops such as groundnut, cotton, wheat, tobacco, Bengal gram, brinjal, sugarcane, eggplant, red gram, banana, tomato, sugarbeet, chillies, potato, soybean, citrus, cauliflower, onion, peas, sunflower, coffee, tea, ginger, turmeric, pepper, betel vine, cardamom etc.

Compatibility

Trichoderma is compatible with Organic manure, and with biofertilizers like Azospirillum, Rhizobium, *Bacillus subtilis* and Phosphobacteria.

Biocontrol mechanisms of *Trichoderma* spp.

Trichoderma spp. is biocontrol agents effective against fungal phytopathogens. They can act indirectly, by competing for nutrients and space, modifying environmental conditions, or promoting plant growth and plant defensive mechanisms and antibiosis, or directly, by mechanisms such as mycoparasitism (Papavizas, 1985; Howell, 2003; Vinale *et al.,* 2008). The mechanisms can be described as:

Biocontrol by competition for nutrients and living space

Trichoderma spp., are rapidly growing fungi that have persistent conidia and a broad spectrum of substrate utilization. They are very efficient competitors for nutrition and living space (Hjeljord *et al.,* 2000). In addition, *Trichoderma* spp., are naturally resistant to many toxic compounds, including herbicides, fungicides, and phenolic compounds. Starvation is the most common cause of death for microorganisms, so competition for limited nutrients is especially important in the biocontrol of phytopathogens. Iron uptake is essential for filamentous fungi and under iron starvation; fungi excrete low-molecular weight ferriciron-specific chelators, termed siderophores. *Trichoderma* spp. produces highly efficient siderophores that chelate iron and stop the growth of other fungi (Benitez *et al.,* 2004). Therefore, soil characteristics influence *Trichoderma* as a biocontrol agent.

Biocontrol by mycoparasitism

The direct interaction between *Trichoderma* and pathogen is called mycoparasitism. As mentioned earlier, Weindling (1932) was the first to recognize that *Trichoderma* spp., is a biocontrol agent and at the same time he also noticed mycoparasitism of *T. lignorum* (viride) hypae coiling and killing *R. solani* (Wells, 1988). Mycoparasitism is a complex mechanism that generally involves the production of a cell wall lytic enzyme. Chet *et al.,* (1998) described that the mycoparasitism process involves four sequential steps: chemotropism and recognition; attachment and coiling; cell wall penetration; and digestion of host cell. *Trichoderma* strains detect other fungi, grow straight towards them, and sequentially produce hydrolytic cellwall degrading enzymes. *Trichoderma* attach to the host, and coil hyphae around the host, form appressoria on the host surface, penetrate the host cell, and collapse the host hyphae (Steyaert *et al.,* 2003).

Plant root colonization by *Trichoderma* spp.

Studies of the early invading fungi *Trichoderma* spp. showed that root colonization stimulated plant defence responses such as induction of peroxidases, chitinases, β-1, 3 glucanase, phenylalanine, and hydroperoxidase lyase; activated signaling of biosynthetic pathways; and caused accumulation of low-molecular weight phytoalexins (Howell *et al.,* 2000; Yedidia *et al.,* 2003; Harman *et al.,* 2004a;). Yedidia *et al.,* (1999) observed the physical interaction between *T. harzianum* T-203 and a cucumber plant under the electron microscope and found that the fungus penetrated the root and grew in the epidermis and outer cortex, which stimulated increases of peroxidase and chitinase. Therefore, the interaction appears to be a symbiotic relationship in which *Trichoderma* lives in the nutritional niche provided by the plant, and the plant was protected from disease.

Trichoderma spp. as natural decomposition agent

Decomposition is defined as the biological process to degrade and break down organic materials into smaller particles that can be used by other organisms. Decomposers/natural decomposition agents such as fungi play a vital role during this process *Trichoderma* strain Effect Crop References *T. harzianum* N47-Increase the number of lateral root and root length. Pea (*Pisum sativum*) Naseby *et al.,* (2000) *T. harzianum*-Increase in cumulative root length, root surface area and the number of root tips Cucumber (*Cucumis sativus*). Yedidia *et al.,* (2001) *T. harzianum* strain M10-Increase germination of tomato seeds and improved the growth of the seedlings-Produce harzianic acid Tomato (*Solanum lycopersicum*) Vinale *et al.,* (2013) *T. harzianum* strain SQR-T037-Give better root development for the enhancement of root length and tips. Promoted tomato seedling growth-Produce harzianolide Tomato (*Solanum lycopersicum*). Cai *et al.,* (2013). *T. virens*-Produce the auxin-related compounds indole-3-acetic acid, indole-3-acetaldehyde, and indole-3-ethanol. ArabidopsisthalianaContreras-Cornejo *et al.,* (2009) T. atroviride-Produce 6-pentyl-2H-pyran-2-one (6-PP), which promoted plant growth and regulated root architecture, inhibiting primary root growth and inducing lateral root formation.

Bio-remediation by *Trichoderma* spp.

The use of *Trichoderma* and some other microorganisms in soil are reported to degrade the chemical contaminants present in the soil. Bioremediation and phytoremediation in association with microbes are innovative technologies having the potential to alleviate various soil pollution problems. The genus *Trichoderma* is genetically very diverse with a variety of capabilities among various strains with agricultural and industrial significance (Tripathi *et al.,* 2013). The potential *Trichoderma* alleviates contaminants by acting upon chemicals, metal contaminants by the activity of various enzymes and improves the physical and chemical properties of soil (López Errasquín *et al.,* 2003), (Hasan, 2016). Heavy metal contaminants like Ni, Cd, Zn, Pb, As has been tolerated and accumulated by *Trichoderma sp*. (López Errasquín *et al.,* 2003), (Tripathi *et al.,* 2013). Agrochemicals application in intensive cultivation has accumulated the contaminants and degrading the soil health and crop performance. *Trichoderma* inoculation in soil has reported to degrade the chemical pollutants and make nutrients available to plants from those agrochemicals too (López Errasquín *et al.,* 2003). In 1930, Weindling first discovered the genus Trichoderm spp. as a biocontrol agent and since then numerous studies have demonstrated that *Trichoderma* is an effective bicontrol agent for phytopathogenic microorganisms (Harman, 1996). A biocontrol program is only established when the bicontrol agent can successfully manage the interaction between the host plant and pathogen. The ability of *Trichoderma* to successfully manage this interaction has been well established. The fungi have also been demonstrated to enhance the defence responses in plants. Thus, as an effective biocontrol agent the use of *Trichoderma* will certainly ensure sustainable disease management.

Trichoderma is one of the beneficial micro-organisms in the agro-ecosystem which influences soil health and crop performance. Its antagonistic feature with plant pathogenic micro-organisms makes it more reliable for use in the agriculture field. However, its use is not limited to anti-pathogenic activity but also acts as biofertilizer, plant growth promoter, bioremediation, and increase in crop yield both biological and economic yield. Thus, the use of *Trichoderma* should be promoted as it promises for sustainable agriculture by reducing the use of harmful chemicals in the agriculture field

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